The loosening of prevailing torque nuts

By Bill Eccles, Bolt Science

Bill Eccles has recently carried out new research to validate his suspicions that axial loading in the presence of transverse joint movement could affect the loosening characteristics of prevailing torque nuts. His findings, summarised here, challenge previous assumptions that these types of nuts will act as loss prevention devices.

Nuts coming loose and detached from bolts is not a new phenomenon. Patents started to appear in the middle of the nineteenth century proposing improvements in bolt and nut design to prevent them coming loose unintentionally.

It has been know for forty years that transverse joint movement can completely loosen non-locked nuts. Once relative motion occurs between the threaded surfaces and other contact surfaces of the clamped parts the bolted connection would become almost completely free of friction in a circumferential direction. The bolt preload acting on the thread, which is sloped, creates a torque in the circumferential direction that results in self-loosening of the nut. The way to stop nuts coming loose is to design the joint so that there is sufficient preload, generated by tightening the nuts, so that joint movement will not occur. That's the theory, but achieving this is not always feasible in that, in many applications, it is difficult to determine the forces acting on a joint and hence whether slip will or will not occur. In these circumstances some kind of locking device is often employed to guard against the nut self-loosening.

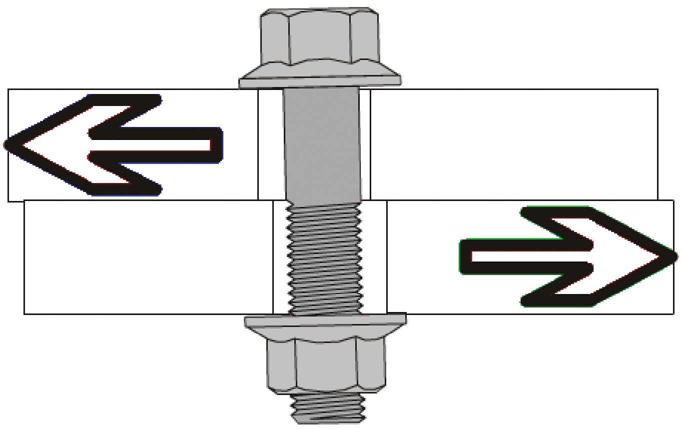

Figure 1 – Transverse joint movement.

Prevailing torque nuts, often referred to as stiff nuts, are one of the commonest methods of providing resistance to self-loosening. Patents for this type of nut began to appear in the 1860s and many of the principal types can be traced back over 100 years. One advantage of this type of nut is that the locking feature can be checked at the time of assembly by measuring the prevailing torque. The present standard test code (ISO 2230) specifies performance requirements to ensure that nuts meet a certain minimum standard. Key requirements are that the first prevailing torque in the tightening direction must not exceed a maximum value and that the first and fifth prevailing torque in the untightening direction must achieve certain minimum values.

There are a variety of prevailing torque nuts, many of them proprietary in design, but in general they can be classified into one of two categories, all-metal and those having a non-metallic insert. Most varieties of non-metallic insert nuts have a polymer ring located on the top face of the nut that generates a prevailing torque when tightened onto a bolt. The all-metal nut achieves a prevailing torque by either distorting the top of the nut by introducing slots, making the top threads elliptical shaped or by the use of spring steel inserts.

In research published thirty years ago it was shown that:

1. The resistance to loosening depends upon the magnitude of the prevailing torque. The higher the prevailing torque the higher is the resistance to self-loosening. The disadvantage of too high a prevailing torque is that torsional stresses are induced into the thread which results in premature yielding that limits the preload that can be achieved.

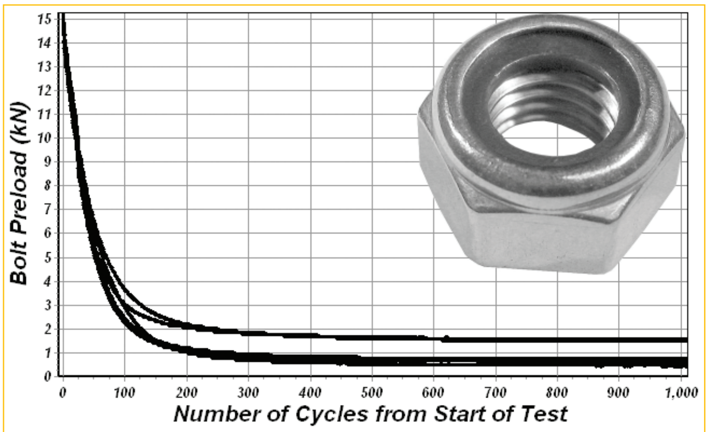

Figure 2 – Typical loosening curves for a prevailing torque nut.

2. Under a standard transverse vibration test (DIN 65151), commonly called a Junker test, prevailing torque nuts tend to self-loosen initially but retain a residual amount of preload. That is, such nuts will partially come loose on test but the loosening will stop when a certain level of preload is achieved so that the nut does not become detached from the bolt. The test involves inducing transverse movement into a joint whilst simultaneously measuring the fastener preload. A typical preload decay graph from such a test for a prevailing torque nut is shown in Figure 2. The curves are for a M8 nylon insert nut being subjected to transverse vibration of amplitude +/- 0.65 mm. After an initial stage of self-loosening nut rotation stops leaving a residual preload in the fastener. Under transverse vibration, prevailing torque type nuts are not truly 'lock nuts' in that they do not fully prevent rotation i.e. the nut is not locked to the bolt.

There have been a number of cases of prevailing torque nuts becoming detached from bolts leading to a catastrophic failure of the joint. The cause of such detachments has not been understood and one reason for this is that such complete loosening has not been able to be reproduced in a DIN 65151 test. Often they have been put down to 'vibration' without explaining details of the mechanism involved. Without understanding progress is at best haphazard.

Study of incidents in which detachments of prevailing torque nuts have occurred indicate that the joint would be subjected to axial as well as transverse loading. Previous published research had indicated that axial loading alone acting on a joint does not result in any significant self-loosening. Research into the fastener loosening process was conducted in conjunction with the Jost Institute of Tribotechnology at the University of Central Lancashire. It was suspected by the author that axial loading in the presence of transverse joint movement would affect the loosening characteristics of prevailing torque nuts.

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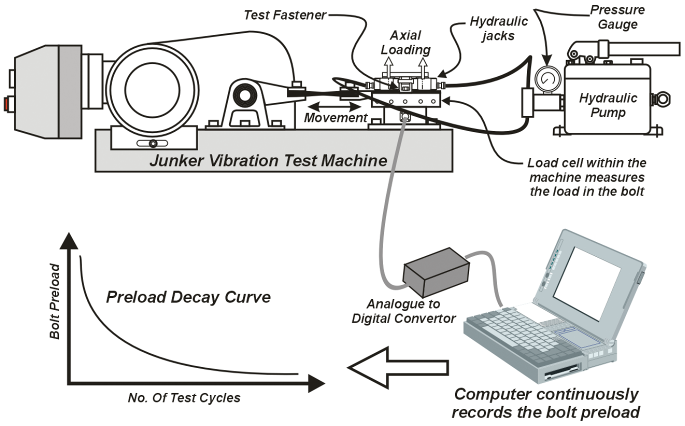

Figure 3 – Test arrangement.

In order to investigate the causes of such nut detachments, a Junker machine was modified to allow axial as well as transverse loading to be introduced into a joint. Details of the modified machine are shown in Figure 3. Miniature hydraulic jacks were used to allow axial loads to be imposed upon the joint whilst transverse movement is occurring. The arrangement allows axial loading alone, transverse displacement or a combination of both to be imposed on the joint.

The experiments conducted using the modified Junkers machine have demonstrated that the combination of axial and transverse load have a profound effect on the loosening of prevailing torque nuts.

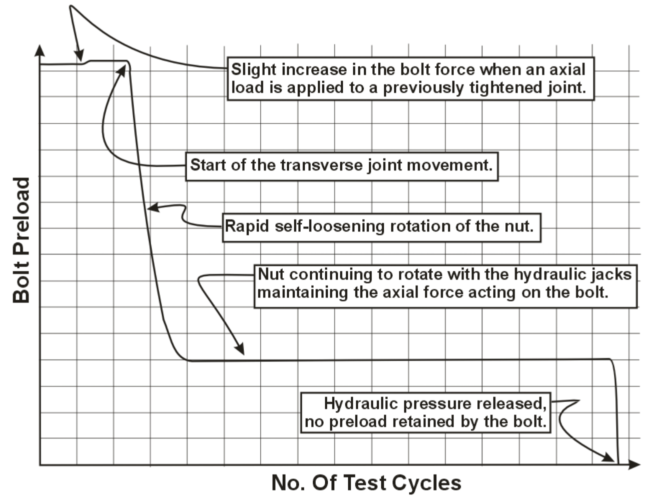

Figure 4 – Loosening of a prevailing torque nut under a constant axial loading as well as transverse joint movement.

The test programme indicated that:

1. If the axial load exceeded the preload retained by the nut on a standard Junker test, continued rotation of the nut occurred until it became detached from the bolt. Under such circumstances, the axial load causes joint separation i.e. a gap would occur between the joint plates resulting in the bolt sustaining all of the axial loading. The axial loading would result in a loosening torque being generated under transverse movement which continues the rotation of the nut until it detaches from the bolt. This is illustrated in Figure 4. The nut is initially tightened and then an axial load is applied. The bolt, at this stage, only sustains a small proportion of the load due to the joint and bolt forming a system of balanced springs. The bolt acts as a tension spring and the joint a compression spring, the tensile and compressive loads balancing each other. The bolt is stretched by only a small additional amount, and hence only sustains a small proportion of the axial load. At this stage, the majority of the axial load is sustained by reducing the amount of compression sustained by the joint. When the machine is started and the joint experiences transverse movement, rapid loosening of the nut can be observed. The preload decreases until the joint separates so that the axial load is sustained entirely by the bolt. As long as the axial load is maintained, the nut continues to rotate until the machine is stopped or the nut becomes detached.

2. If an intermittent axial load were applied, when the load was above a threshold value, nut rotation would occur. The threshold value being equal to the residual preload retained by the bolt under a standard Junker test. If such loading was repeatedly applied to the joint complete loosening of the nut occurred. If such loading was further continued, detachment of the nut from the bolt would occur. This is illustrated in Figure 5. The dotted line shows the loosening curve if no axial load was applied.

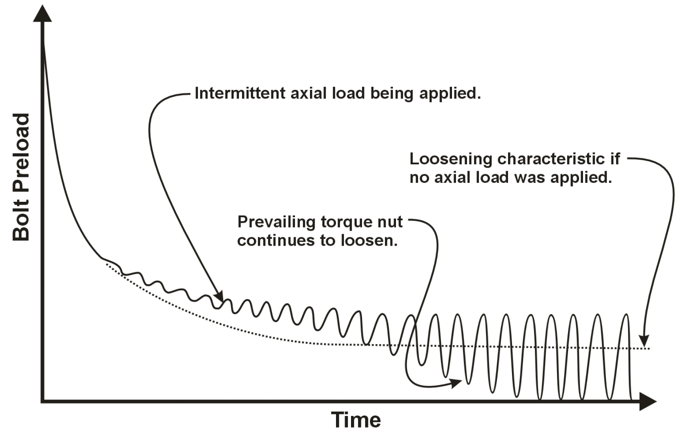

Figure 5 – Loosening of a prevailing torque nut under an intermittent axial loading as well as transverse joint

The research is also relevant to plain non-locking nuts as well as prevailing torque nuts. In the presence of axial loading, plain nuts can become readily detached from bolts. Even a very small axial load in the presence of transverse joint movement will lead to detachment.

The loosening torque generated when transverse movement occurs depends upon the magnitude of the bolt preload. The higher the preload, the higher is the loosening torque. With prevailing torque nuts, loosening under transverse vibration occurs until the loosening torque is resisted by a prevailing torque equal in magnitude. Once sufficient self loosening occurs so that the axial load is greater than the remaining preload, it is the axial loading that generates the loosening torque and it is this that rotates the nut so that it becomes detached from the bolt.

This study does not mean that prevailing torque nuts are now obsolete or cannot perform a useful function but it does point towards caution when used in applications in which transverse joint slip can occur and axial loading is also sustained.

Based upon the experiments completed and the measurements made, the effect of applying an axial load when transverse joint movement is occurring is to aid the self loosening tendency of prevailing torque nuts. Whether or not complete loosening of this type of nut will occur under transverse joint movement depends upon the magnitude of the applied axial load.

DIN, the German standards body, has previously classified such fasteners as loss prevention devices. That is, although they may loosen they will not become detached from nuts when tested on a Junker machine. This may need revision in the light of this work.

The author would like to acknowledge the help and assistance of Professor Ian Sherrington and Professor Derek Arnell of the Jost Institute of Tribotechnology at the University of Central Lancashire.

Further details of this research are available in the Proceedings of Mechanical Engineers, volume 223, part C: Journal of Mechanical Engineering Science.

Visit www.boltscience.com for extensive information on bolted joints as well as how to contact Bill Eccles.